Meeting Requirements of Older Users? – Robot Prototype Trials in a Home-like Environment

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Abstract. A prototype of an assistive robot for older people was tested in three different countries in life-like lab settings. A sample of potential older users with different grades and types of age-related impairments completed a sequence of tasks with the robot. Subsequently, usability issues, user acceptance, and their willingness to pay for such a robot (affordability) were assessed to find out if the robot caters to the needs of the impairment groups. Main results of the data analyses were: ease of use was deemed satisfactory by the majority of participants. Task speed was considered to be rather slow. Additionally, it could be shown that participants were sceptical of buying a robot for their own use, but would be willing to rent one. A significant difference in classifying the robot prototype as helpful for the home was found in participants with mobility impairments compared to participants without mobility impairments.

Keywords: social robotics, human-robot interaction, assistive technology, user requirements, older users, prototype trials.

1 Introduction

In view of the demographic development in Europe [1] with its rising number of older people, Assistive Technology becomes an essential element to improve senior citizens' quality of life. Robotics could contribute to helping senior citizens stay longer at their own homes and feel safe. Solutions in robotic technology, however, not only need to be reliable in terms of task performance, but also have to meet users' acceptance and fulfil their needs. Acceptance is described as "the demonstrable willingness within a user group to employ technology for the task it is designed to support" [2].

Several European projects in the field have attempted to tackle this issue. The most recent examples (among others) are KSERA [3], DOMEO [4], Companionable [5], SRS [6], or Accompany [7].

The HOBBIT-project aims at developing a highly acceptable and affordable socially assistive robot supporting older adults in staying independently at home. To become a real benefit for senior persons, such a robotic solution needs to cater to the target-groups needs. As people age, they become more fragile and may become more dependent on other people to accomplish everyday life activities [8]. Especially falls and their consequences are often considered a contributing reason for admission to a nursing home [9, 10]. People decide to move into a care facility, because they do not feel safe in their own home after a fall, or they are in need of more intense care due to the health consequences of a fall. Assistive technology thus should help preventing falls and improve emergency handling.

As Hegel et al. (2007) found [11] the more an application is used in a private context, the higher the intensity of interaction. Accordingly, an everyday benefit needs to assure frequent usage of a robotic assistant. As a consequence, HOBBIT should fulfil tasks at home which reduce risk of falling (i.e. keeping floors clutter-free, searching and bringing objects), and offer further functionalities that focus on user needs. Using HOBBIT on a daily basis will also facilitate its implementation in the household. It has been found that users' expectations are often hard to meet in real interaction [12]. In order to identify such benefits, the analysis of user requirements plays an important role.

The following section briefly describes the findings about user requirements leading to the functionalities of the prototype, section 3 described the prototype used for the trials, and section 4 then described the trial procedure and the most important results. Finally, conclusions are drawn from the trial results (section 5) and the study is discussed with an outlook to future work (section 6).

2 Assessment of User Requirements

In order to guarantee high usability and user acceptance, the conception of HOBBIT followed a user-centred approach. Several iterative pre-studies led to the identification of needs and requirements of older persons that formed the basis of functionalities in the prototype trials. Based on the idea of focus groups [13] four creative workshops were conducted in Austria and Sweden with older participants and people who had a direct connection to the topic of "age and assistance at home" (medics, therapists or relatives of older people) [14]. These led to first explorative results concerning user expectations and requirements of a robotic helper at home. Requirements mentioned by the workshop participants mainly concerned household tasks (which is in line with findings from literature [15]), emergency detection, and providing/supporting social contacts. Some functions mentioned were beyond technical feasibility, for instance complex or physically demanding household tasks, and thus were not taken further into consideration within the HOBBIT project.

As a next step, a questionnaire, based on this preliminary collection of ideas, was handed out to senior citizens in Austria, Greece and Sweden. Questionnaire items covered feasible, helpful functions identified in the workshops, and design issues to assess acceptance of HOBBIT. 113 potential primary users (PUs) aged 70 or older completed the questionnaire. Results of this survey led to a clearer picture of (technically feasible) functions that were important to older persons, but also what operation mode they would prefer, and basic design preferences.

Finally, 38 potential PUs were interviewed, in order to gain more details about user's needs and ideas regarding the interaction with the robot. In combination with the findings from workshops, interviews, and literature on falls and fall prevention in elderly, the identified user requirements were translated into technically feasible functionalities of a first HOBBIT prototype (PT1).

3 The HOBBIT Prototype

The prototype used in the trials is a mobile platform equipped with a multitude of sensors for navigation and perception purposes. To fulfil the tasks the robot has one light-weight arm with five degrees of freedom. The arm features a gripper based on the FESTO "Finray effect". Thus, a number of small everyday objects can be grasped.

As user requirement assessments have also shown, it is vital to offer different modalities with which to operate the robot. The centre of this approach with HOBBIT is the multi modal interface. It consists of a tiltable touch screen, automatic speech recognition, text to speech functionality and also a gesture recognition interface.

On a 'face screen', HOBBIT displays positive and negative facial expressions as a means to communicate with the user. Altogether, the size of PT1 is approx. 1.20m.

A more detailed description of PT1 components and specifications is given in [16].

Fig. 1 *HOBBIT PT1*

4 Trials

The aims of these trials were:

- Assessing if user requirements were met by functionalities of the HOBBIT.

- Gaining an insight into the usability, acceptance and affordability notions of potential older users, and to collect data for improvements to be implemented in a second prototype.
- Analysing if the type of participants' impairments had an influence on their perception of the robot.

4.1 Sample and Setting

4.1.1 Sample

Representative PUs were recruited in Austria, Sweden and Greece. All participants were 70 years or older and had at least moderate, typical age-related impairments. The most common age-related impairments occurring at that age were identified from literature [17, 18, 19, 20]. These are: vision, hearing or mobility impairments. Cognitive impairments were an exclusion criterion for participation in the trials.

In order to assess grade of impairment (from "none" to "severe"), all participants were asked to complete a screening questionnaire before taking part in the trials. The screening questionnaire consisted of 18 items formulated as statements to be answered on a 4-point Likert scale, in order to find out about PUs' difficulties regarding vision, hearing and mobility. Additionally, all participants were asked how often they used a computer and if they had ever fallen at home. It was expected that multi-morbidity would occur in the sample group, i.e. that there would be PUs with several limitations. PUs who had no form of impairment in the screening questionnaire were excluded.

Apart from the impairment grading, PUs had to fulfil the following inclusion criteria for PT1 trials:

- Men and women aged 70+
- Single-living at home (due to considerations that acceptance of an assistive robot among senior couples might be lower than for single-living persons)
- Possibly also receiving (moderate) home care; help in the household
- Sufficient mental capacity to understand the project and ability to give consent
- No pacemaker

The final sample consisted of 49 PUs (between the age of 70 to 88 years; 35 female and 14 male) and 35 accompanying relatives or close contact persons (so-called secondary users; SUs; 24 female and 11 male). In Austria 12 PUs and 9 SUs took part in the study; in Sweden 21 PUs and 11 SUs and in Greece 16 PUs and 15 SUs.

78% in the PU sample had at least one impairment graded as "moderate". 44 PUs (89.8%) had some form of multiple impairment. Six participants had a severe vision impairment (12.2%), four had a severe hearing impairment (8.1%) and three had a severe mobility impairment (6.1%).

4.1.2 Setting

Two pilot trials were carried out with PUs in Austria before, in order to test the wording and comprehensibility of the used questionnaire items and robot dialogue, and length of trials in general.

Trials took place at three sites from March 2013 until May 2013. The setting consisted of two adjacent areas with separation screens and a doorway in between at all three sites (Austria, Greece and Sweden). There was a Briefing Area/Kitchen that consisted of a kitchen corner (sideboard, a small oven/cooker, dishes, dishtowels and cutlery) and an eating area with a table, two chairs and a side table.

The other area was the Main Testing Area, decorated as a living room: a cosy chair for the PU, a small couch table, a chest with drawers, and space in the background for SUs, the observer, and a technician who remained in the background to navigate the robot with remote control and assure that the robot functioned correctly. This semi-autonomous setting allowed for a controlled, yet still realistic test of the robot's functionalities in pre-defined scenarios.

Fig. 1. Kitchen area at trial site in Austria

Fig. 2. Living room area at trial site in Austria

4.1.3 Measures & Procedure

After an introduction of the project, signing of informed consents and a short introduction of the robot and how to use it, PUs were seated in a chair in the living room area and given written instructions for each task. After each task, there was a short break for usability questions (based on the NASA Task Load Index [21], plus a few individual items). After the series of tasks, a debriefing questionnaire for PUs (including the System Usability Scale [22]) and SUs, time for questions from the participants and a snack ended the trial. Questions of the debriefing questionnaire, apart from a few open-ended items, had to be answered on a 4-point Likert scale. To obtain a further external assessment of the participant's behaviour and attitude towards the robot during interaction, a structured observation protocol was used by an observer who was present, as well as the SUs.

One trial lasted on average 2.5hours (including introduction and debriefing questionnaire). If wanted, participants could take breaks in between.

Based on the user requirements, the following sequence of tasks was chosen for the trials:

- Call the robot (via a call button from the other room)
- Clear floor (PU commanded the robot to autonomously pick up an unknown object from the floor and put it on its tray)
- Teach an object to the robot (PU taught robot a new pre-defined object by putting it on a turntable that the robot grasped)
- Search and bring (PU commanded robot to search and bring a learned object from the adjacent room)
- Emergency call (a project member simulated a fall which triggered HOBBIT's emergency dialogue. PUs completed a verbal dialogue with HOBBIT finally establishing a demo-emergency call.)

4.2 Analysis

Quantitative data were analysed using SPSS 18. The data from questionnaires were subject to frequency analyses, correlations and non-parametric tests on significance (i.e. Mann-Whitney-U-Test). Additionally, qualitative data from observation forms were analysed descriptively and added interesting information.

4.3 Results

4.3.1 Usability

On the Nasa Task Load Index, the majority of PUs rated the tasks as being "rather" or "very easy". Task-speed of the robot was mostly perceived as being rather slow. Only 18.4% of the PUs found the robot complex, and despite a whole lot of new information in the briefing phase and the new situation of interacting with a robot, only 32.6% felt that they needed to learn a lot beforehand. 91.9% thought HOBBIT was easy to use in general. PUs were also asked to rank which mode of operation they preferred in the debriefing questionnaire. The result showed the following order: voice commands came first (49%), then touch screen (42.9%) and gestures (6.1%).

SUs (n= 35) also chose voice most often as their preferred option (49%), touch screen was in second place (16.3%) and then gestures (2%). This, however, also has to be connected to the fact that only two gestures (yes and no) had been integrated at that point which explains the higher interest in voice and touch screen.

Qualitative data from the observation protocols provided important information: On the whole, the observers noted that most participants were sceptical or insecure in the beginning, but then became more and more confident in the interaction with the robot. Icons and font size were liked by PUs, but a few participants stated that they had problems with recognising them and that the text should be larger. It was furthermore often observed that participants began with speech in a task as the preferred interaction mode and then switched to the touch screen. Speech commands, even though very much appreciated in the user needs assessments before the trials, posed problems for many PUs: participants did not feel at ease or could not remember the speech commands for HOBBIT. Most participants often talked in the natural way one would use when talking to a human being, which often led to speech commands not being understood by HOBBIT.

PUs using a computer more frequently also stated that they would like to use the robot more frequently (r=.44/p=.01). At the same time, a significant negative correlation was observed between the amount of computer use and finding the robot "awkward to use" (r=-.39/p=.02).

Bearing age-related impairments in mind, the question remained, whether HOBBIT catered to requirements of older users. Mann-Whitney-U-Tests showed that hearing impairments had a notable effect on the emergency task: PUs with hearing impairments found accomplishing this task more difficult (p=.048) than the other PUs. Accordingly, PUs with hearing impairments liked using the touch screen significantly more than other PUs (p=.030). No other significant differences between types of impairments were found.

4.3.2 Functions Supporting User Acceptance

The debriefing questionnaire mainly focussed on functionalities that were classified as high priority functions from user requirement assessments and which were also in keeping with the HOBBIT approach of fall prevention. These were tasks that could be subsumed under 'household' and 'care'. Other data that was collected in the questionnaire covered design issues. In the following, the main results are presented.

a) Household: PUs ranked fetching objects from the floor as the most important picking up-function (49% of the sample), followed by fetching objects from a high shelf (32.7%). The same result was found for SUs. 52.2% chose 'picking up objects from floor' as the most important function. 77.6% of the PUs and 53.1% of the SUs furthermore found a transporting functionality important.

The grade of mobility impairment and agreement to this question were significantly correlated (r=.314/p=030), which means that a high grade of mobility impairment was linked to PUs finding it important that the robot could transport objects. What is more, finding it important that the robot transports objects correlated significantly with finding it important to use the robot as a walking stick (r=.285/p=.050), as an aid to stand up from the floor (r=.395/p=.006) and as an aid to stand up from a chair (r=.448/p=.001).

b) Care: Using the robot as a walking aid and as a stand up support, either from the floor or from a sitting position, were identified as possible fall prevention functionalities in the user requirement assessments. PT1 did not feature such functionalities, but the participants were asked how important they would be to them. PUs chose the aid to stand up from the floor most often as the preferred one (55.3%), standing up from a chair was in second place (18.4%), and the walking aid in third place (15.8%). In the same ranking, SUs chose standing up from the floor as the most preferred option (36.7%), walking aid second (16.3%) and then standing up from a chair (14.3%). Asked about the importance of such functionalities in general, 65.8% of the PUs stated, that help in standing up after a fall was “very important” to them. Importance of mobility aids was less distinct among SUs.

Asked about the emergency dialogue in the trials, feedback from PUs was very positive: length of the emergency dialogue was rated as “just right” by 91.8% of the PUs, the speed by 87.8%, and spatial distance between robot and user in the emergency scenario was rated “just right” by 81.6%. When asked whether they found the emergency dialogue calming, 32.7% of the PUs chose “rather” and 53.1% “very much”.

57.2% were in general favour of having a robot at home for a longer period, and even more (65.3%) could imagine that HOBBIT takes care of them. 49% found the robot as they experienced it “rather” or “very helpful” at home. SUs were also asked to state how helpful they thought HOBBIT was for their relatives/acquaintance’s home. They were slightly more positive than the respective PUs: 42.9% chose “rather” and 10.2% “very much” as answers, which in total makes 53.1% agreeing that such a robot could be helpful.

Again, HOBBIT’s functionalities seemed to especially cater to PUs with mobility impairments. There was a significant correlation between mobility impairment and the opinion that the robot could be helpful in one’s own home ($r=.372/p=.009$).

Results of U-tests confirmed an expectable difference between persons with a mobility impairment and PUs without. Mobility impaired PUs found it more important to use the robot as a walking aid ($p=.007$) and could also imagine having a robot taking care of them significantly more ($p=.038$). At the same time, they judged the robot to be less useful without an arm ($p=.005$), hinting at the importance of picking up objects for this group once more, and generally found PT1 more helpful for their home than PUs without mobility impairments ($p=.001$). No significant differences were found for other impairment groups.

c) Design: Even though PT1 still possessed a very rudimentary design and thus could not give the impression of a finished product, a few questions regarding design were included in the debriefing questionnaire. PT1’s basic design already had been developed with the goal of approaching user requirements assessed beforehand. Those were: anthropomorphic design with head/face and body, an arm, and a moderate height that would not intimidate sitting participants.

PUs were asked how they liked the face and the voice of the robot after they had interacted with PT1 in the trials. 69.4% enjoyed the face design (34.7% each rating it with either “liked it very much” or “rather liked it”) and even more (87.8%) enjoyed the voice. On the whole, the female voice was slightly preferred over the male voice: 55.1% of the PUs chose the female voice for interaction in the trials.

SUs were less enthused by the face. Only 16.3% liked it “very much”. The voice was generally liked (over 60% giving it positive ratings), but some SUs said they would like a less ‘mechanical’ and more ‘natural’ voice.

Another question addressed the robot’s size. 51% of the PUs found it the “right size” for being helpful at home, yet 40.8% stated it should be “smaller”. From the SUs, 40.8% found the size “right” and 26.5% said it should be “smaller”.

Among the SUs, liking the design was significantly correlated with imagining to buy the robot for one’s relative ($r=.405/p=.020$) and renting it ($r=.361/p=039$), thus emphasising the influence that design can have on acceptance. No similar correlations were found among the PUs.

4.3.3 Affordability

Asking persons about willingness to buy something they hardly have any experience with and which only exists as a first prototype at the moment of the survey can lead to vague results at best. Nonetheless, we let PUs and SUs reflect on whether they could imagine buying and/or renting a HOBBIT.

The realistic price of the prototype amounted to € 14.000. This was clearly far too costly for the participants. Only 4.1% of the PUs could "rather" imagine purchasing HOBBIT for that price. Nobody agreed "very much" to do so. Buying a HOBBIT in general (without giving a specific price), however, met with slightly more approval. 4.1% could "very much" imagine doing so, and 30.6% could "rather" imagine buying it in general. 49% could "very much" imagine renting a HOBBIT.

The SUs also found the realistic price not acceptable. Still, 2% could "very much" imagine spending € 14,000 and 4.1% opted for "rather". 18.4% could imagine buying a robot for their PU in general. This is still not a very high number, but indicates that SUs are to be seen rather as the marketing target group instead of PUs. Renting the robot was a "very" attractive thought for 22.4% and "rather" conceivable for 26.5%.

Nonparametric correlations showed obvious, yet nonetheless interesting linkages: Those PUs who stated that they would like to use the robot frequently were also more prone to buy a robot in general (r=.458/p=.001). Additionally, the more they thought the robot could be helpful in their home (r=.390/p=.007) and the more they could imagine having a robot at home for a longer period (r=.326/.025), the more they also could imagine buying the robot in general. Hence, only when perceiving the robot as reliable and helpful, buying it can become a realistic option for PUs. Interestingly SUs of PUs with a vision impairment could imagine buying such a robot for their relative significantly more than SUs of participants without a vision impairment (p=.034). There were, however, no significant differences among PUs with different types of impairments observable.

5 Conclusions

The trial results presented here generally indicate that user requirements are met by HOBBIT. PUs mostly enjoyed the trial situation, found the tasks easy to accomplish and the operation of HOBBIT clear. As with all prototypes, some definite areas that are in need of improvement, in order to fulfil the target users' needs, could be identified: dialogues and instructions from the robot have to be legible for users and must not contain "loops" which can lead to frustration, if people are asked the same questions repeatedly. In the learning task it was often unclear and complicated for older participants to know what to do with the robot. Speed of the robot might also be something to be improved. The design of the touch screen menu seems usable for PUs. Minor changes are necessary, though, regarding a clearer arrangement of menu icons, and an adaptable font size to better accommodate PUs with vision impairments.

In terms of acceptance, picking up objects from the floor has been singled out as the function within HOBBIT's range that is most important for older users, especially in case of age-related mobility issues. This is followed by picking up objects from a high shelf and a transport function of the robot. A stand-up and a walking aid are highly interesting for the participants in the trial sample.

The design clearly was not a finished one at this stage, which was also clear to the participants. Some helpful conclusions can nonetheless be drawn from participants' replies regarding design issues: robotic voices should try to approach 'natural' human modulation and style. For an improved version of HOBBIT, also several voice options for each gender could be implemented. The size of a social robot for older persons should not be intimidating; 1.20m might already be too much in some cases. At the same time, it needs to be considered that PUs in a home setting will not always be in a sitting position when interacting with HOBBIT.

Finally, results on affordability showed that the prototype price was too expensive for the majority of participants, but feedback often included that a final working model of HOBBIT could be worth the money. From the sample, SUs seemed more likely to be a market target group, purchasing or renting a robot for their older relatives. Apart from financial resources, this also reflects scepticism among older people to use robots as assistants in the near future. A renting model is preferred and might reduce scepticism from PUs.

Differences between impairment groups could be analysed, which show that the functionalities are catered to meet requirements especially of mobility impaired users. Rating of functions indicates HOBBIT's intended helpfulness in terms of fall prevention. The multimodal operation of HOBBIT (screen, voice and gestures) could make up for difficulties certain impairment groups might face in some tasks.

6 Discussion

The findings presented here also must be viewed from a critical point of view as well. PUs generally gave positive feedback on the prototype. This is not unproblematic. Older participants tend to give favourable comments to developers rather than voicing their opinion, thereby being very positive about prototypes they are presented and tending to blame themselves rather than the interaction modalities if not being able to cope with the system [23]. Self-reporting can also be influenced by age-related factors. [24] showed, for example, that there are age differences in the ways in which people respond in self-reports. Hence, findings from the PT1 trials have to be judged as tendencies which have to be confirmed or further looked into in future research.

Another limitation of this kind of trials is the rather small sample size and the difficulty to arrive at a balanced number of women and men. One also has to consider that participants were in a controlled environment and trials followed a clearly structured sequence of tasks. To gain more reliable and in-depth feedback from elderly users' experiences, and to gain insight to specific situations in which the robot is perceived as either helpful or impractical, long-term trials in a natural home environment would be necessary, which leaves room for future scientific work.

The main focus of this paper was on the question if user requirements based on age-related difficulties were met by our prototype. Despite the fact that findings partly did differentiate between impairment groups and it could be shown that mobility impaired participants rated the robot significantly as more helpful than the other groups, screening impairments by means of a self-report questionnaire has certain weaknesses. It was, for instance, observed that some participants rated themselves fitter than they actually appeared when being observed in their movements during the trials. Using a more 'objective' screening method, such as easy medical tests, for instance, might have led to an even more reliable group of potential users. Yet, such methods would have required the assessment of medical experts. Such an approach, however, must be judged from an ethical point of view as well. Subject older participants, who are a 'vulnerable' target group, to medical assessments would turn the participants into the objects of testing and research instead of the robot prototype. This clearly cannot be the aim of a usability study.

To gain more insight into affordability and attitudes of users, it will be necessary to ask them about their own cost ideas and maybe use a different methodology. As PUs and SUs in this project are expected to have little to no experience with robots, open answers about willingness to buy a product that has only been experienced in a controlled environment and in prototype status are to be treated carefully. Again, assessing price details is more plausible in a setting with an already more finished version of HOBBIT (in terms of design, behaviour and functionalities).

It follows that future work will have to concentrate on long-term trials in homes of potential uses with respective age-related impairments. For results on acceptance in real life, it needs to be made sure that assistive robots give (older) users a feeling of helpfulness and safety on a long-term basis.

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